PERFORMANCE OF ANALOG DEVICES OP284 OPERATIONAL AMPLIFIERS UNDER WIDE TEMPERATURE CYCLING

Test Report

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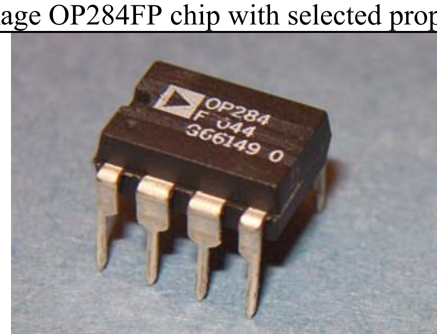
Background

The Analog Devices OP284FP is a precision rail-to-rail operational amplifier. The device can be operated from a single +3 to +36V supply or a ±1.5 to ±18V dual supply. This low noise, 4 MHz bandwidth precision amplifier is useful for a wide variety of applications, such as filters, instrumentation, power supply control and buffers for transducers [1]. The 8-pin plastic DIP device is specified for operation in the temperature range of –40 °C to +125 °C, and is ideal for use with a CMOS digital-to-analog converter to generate a digitally-controlled voltage with a wide output range.

Test Setup

Two circuit boards, each populated with an OP284FP chip, metal film resistors, and COG ceramic bypass capacitors, were constructed for evaluation in the temperature range of +125 °C to -185 °C. The circuits were designed in an inverting amplifier configuration. Each OP284FP device, which had an 8-pin plastic DIP package, was inserted into an IC socket on the circuit board. A photograph of the chip along with some of the manufacturer's specified properties are shown in Table I [1]. The industrial-grade devices were evaluated for packaging durability and electrical performance. The electrical properties, which included signal gain and phase shift, were measured as a function of temperature in the frequency range of 1 kHz to 10 MHz. At each test temperature, the devices were allowed to soak for 15 minutes before any measurements were made. A digital oscilloscope was used to capture the waveforms of the input and output signals of the inverting amplifier.

Table I. The 8-pin plastic DIP-package OP284FP chip with selected properties.

OP284FP IC chip		
Parameter	**Symbol**	**Value**
Input Bias Current	I_B	60 nA
Input Voltage	I_V	0 – 5 V
Slew Rate	SR	2.4 V/µs
Settling Time	τ_S	2.5 µs
Gain Bandwidth Product	GBP	3.25 MHz
Phase Margin	Φ_O	45 degrees

Limited thermal cycling, a total of 60 cycles, was also performed on the OP284 devices. These tests consisted of initially subjecting the two devices to 10 thermal cycles in the temperature range between +90 °C and -185 °C. This was then followed by 50 cycles between +115 °C and -120 °C. A temperature rate of 10 °C/min was used throughout this two-run cycling activity. Physical inspection and electrical characterization of the devices were performed before and after completion of the thermal cycling.

Results and Discussion

As was mentioned earlier, two devices of OP284FP amplifiers were investigated in this work. The data obtained on both devices were very similar; therefore, the results of only one device are presented in this report.

Packaging and Material

Microscopic examination and x-ray scanning were performed on the two devices before cycling, after the first thermal cycling run (10 cycles between +90 °C and -185 °C), and after the second thermal cycling run (50 cycles between +115 °C and -120 °C). All of these tests have revealed no evidence of layer delamination, surface and internal cracking, connection breakage, or solder fatigue for either device. It is evident, therefore, that the exposure to extreme temperatures (namely +115 °C and –185 °C), and thermal cycling (a total of 60 cycles) did not produce any effect on the devices' material or their packaging.

Electrical Performance

Figure 1 shows the gain of the amplifier at various test temperatures in the frequency range of 1 kHz to 10 MHz. The roll-off frequency, which corresponds to a gain of –3 dB, occurs at about 350 kHz. It can be seen that the gain does not exhibit any significant change with variation in the temperature from +125 °C to –150 °C. No effect of temperature on the phase shift property of the amplifier is observed in the low to medium frequency range, as shown in Figure 2. At high frequencies (>100 kHz), however, the phase shift seems to undergo changes with change in temperature. These changes appear to be more profound at the high test temperatures; i.e. +90 °C and +125 °C, as depicted in Figure 2.

The gain and phase properties of the amplifier as a function of frequency at the test temperatures of 25 °C and –185 °C are shown in Figure 3. It can be seen that while the gain exhibits changes due to the extreme low temperature exposure only at frequencies beyond 200 kHz, the phase behaves differently at a frequency as low as 5 kHz. In fact, this low temperature-induced behavior in the amplifier's phase prevails at almost all test frequencies.

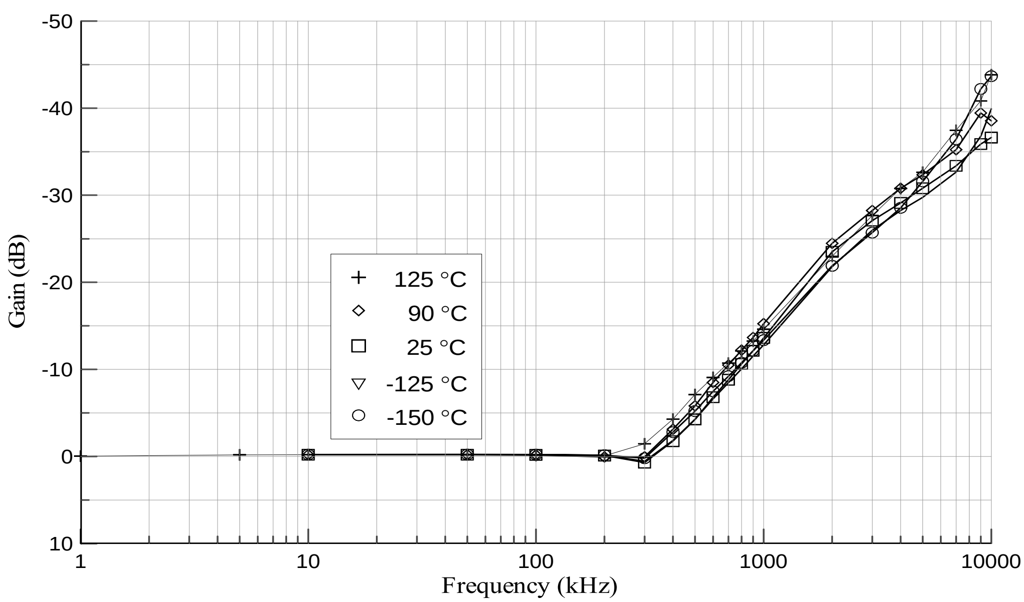


Figure 1. Gain versus frequency at various temperatures.

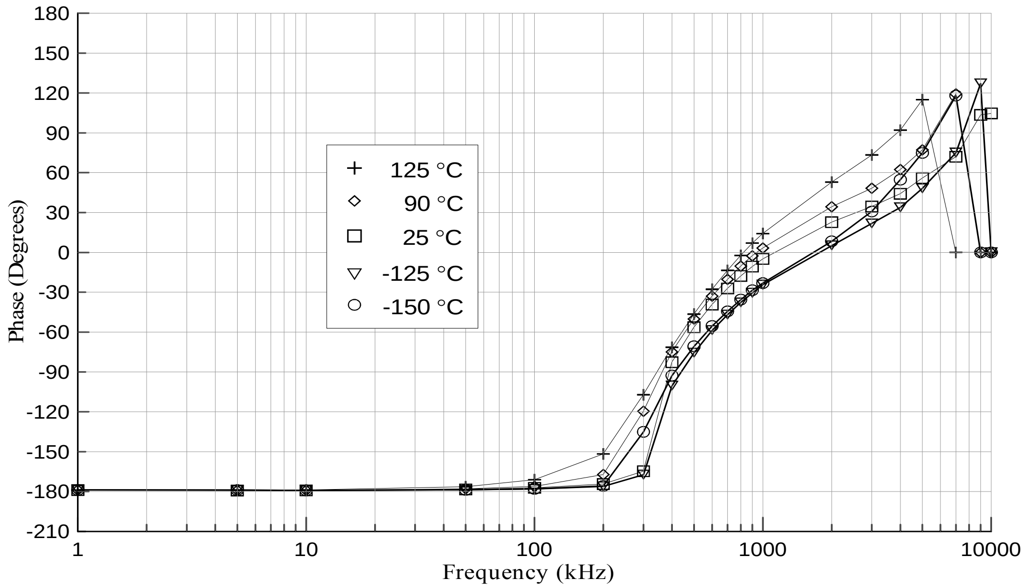


Figure 2. Phase shift versus frequency at various temperatures.

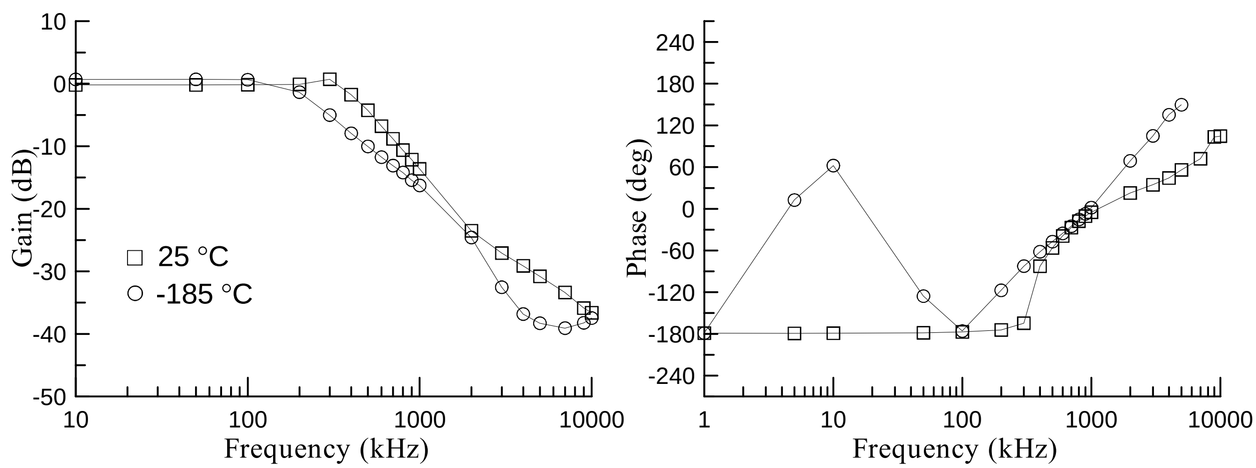


Figure 3. Gain and Phase versus frequency plots at –185 °C and 25 °C.

The amplifier's gain as a function of frequency at test temperatures of 125, 90, 25, -125, and –150 °C is shown in Figure 4. The depicted results represent those obtained before as well as after the thermal cycling, including those of post 10 and post 60 cycles. The results presented in Figure 4 indicate that this applied thermal cycling has had a negligible effect on the gain behavior of the amplifier at any given test temperature and at all frequencies. Similarly, the phase shift did not undergo any changes due to thermal cycling, as shown in Figure 5.

Waveforms of the input and the output signals of the amplifier at 1 kHz frequency are depicted at various temperatures in Figure 6. These waveforms were obtained at 125, 25, -100, -150, and –185 °C before the thermal cycling, and at 25 °C after completion of the thermal cycling. With the exception of –185 °C, the amplifier's signals did not change, in either shape or amplitude, with temperature. At the lowest test temperature, i.e. –185 °C, the output signal of the amplifier, however, exhibited slight alteration only in

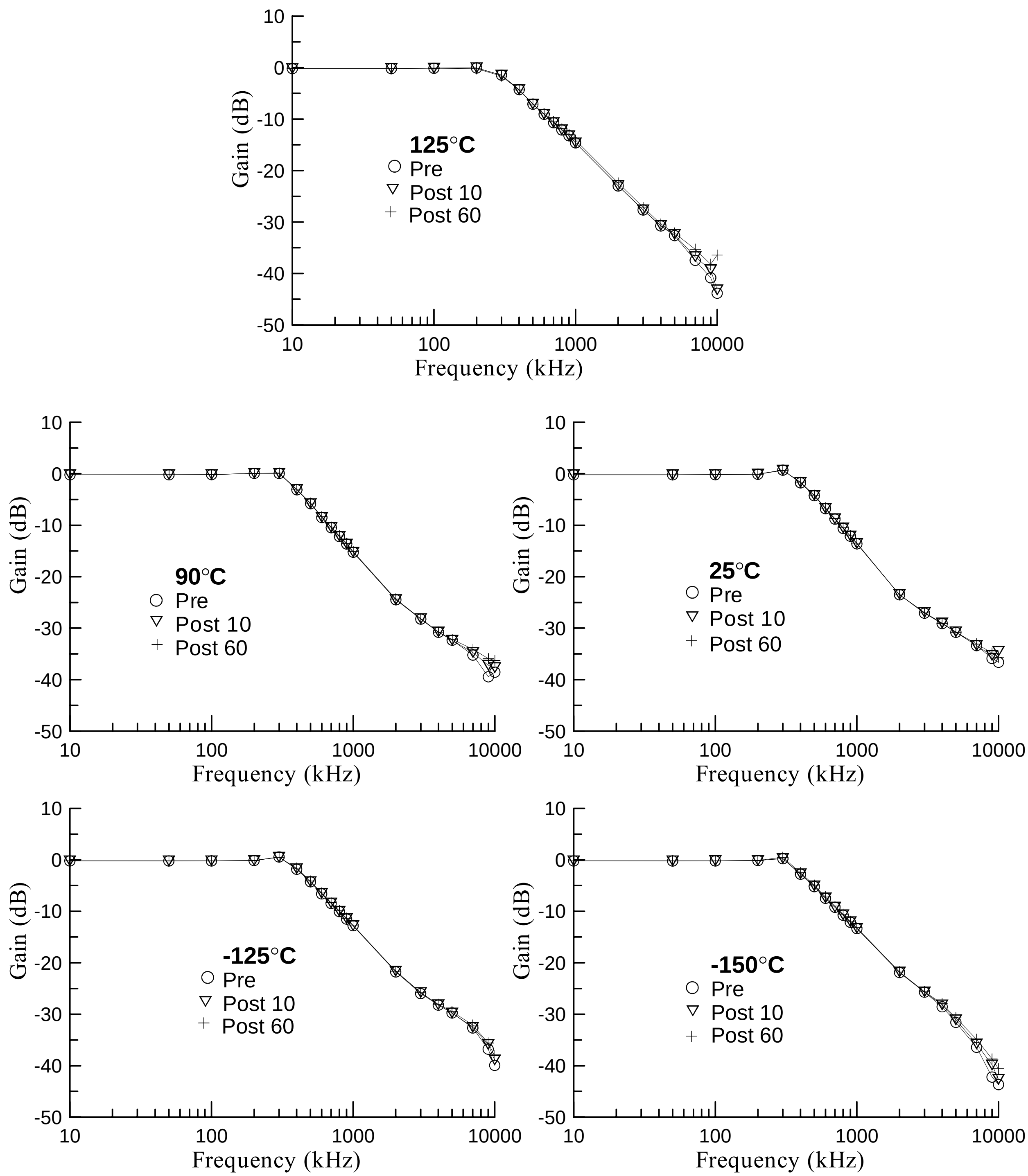


Figure 4. Pre- and post-cycling characteristics of gain versus frequency at various temperatures.

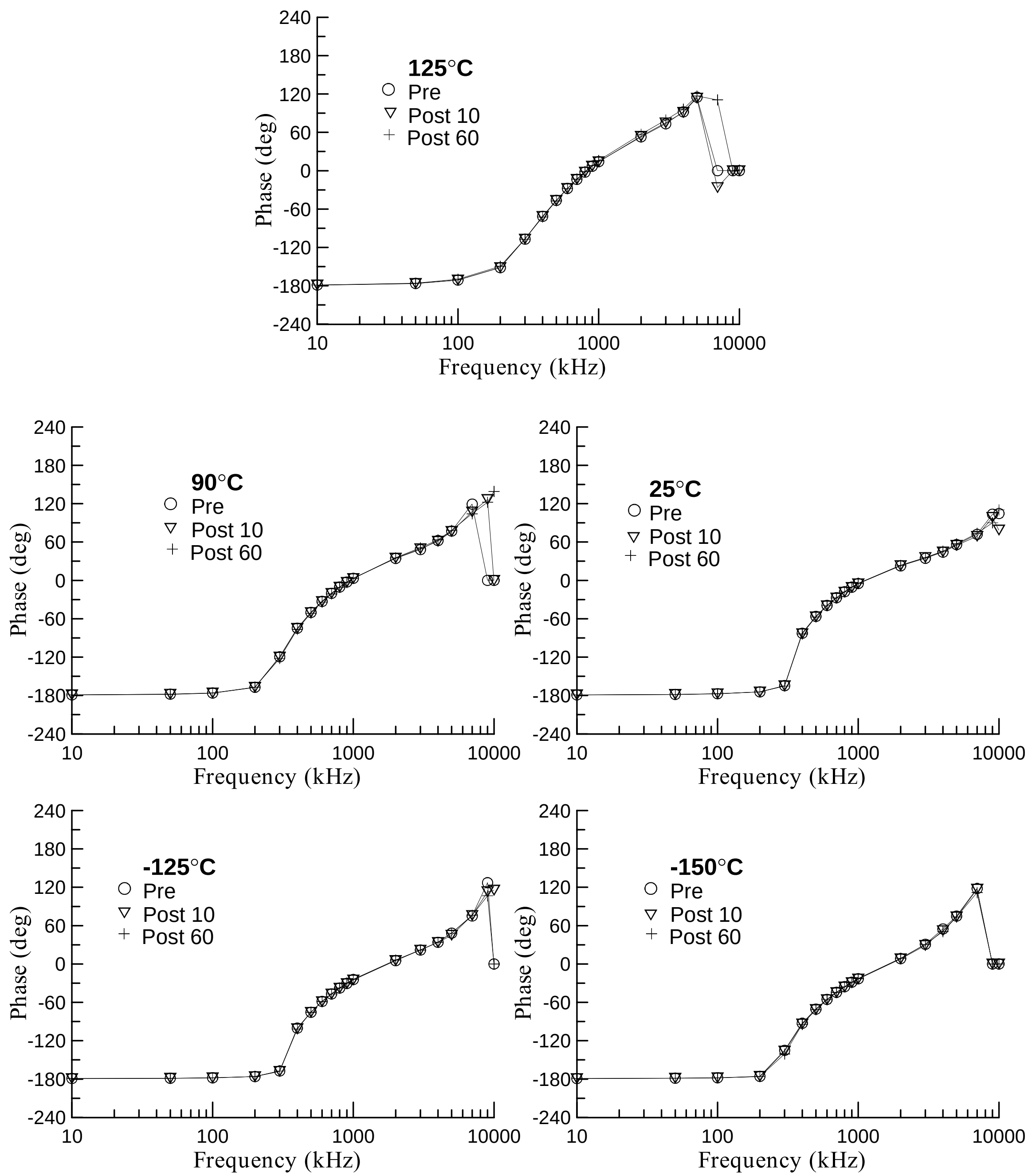


Figure 5. Pre- and post-cycling characteristics of phase versus frequency at various temperatures.

its shape while retaining its magnitude. This behavior in signal distortion was, however, temporary as the amplifier recovers as indicated by the 25 °C post-cycling data in Figure 6.

Similar trend is observed in the amplifier's input ant output signal when the test frequency is increased to 10 kHz. At this frequency and at –185 °C, the amplitude of the output signal is still the same but the distortion in the waveform occurs mostly at the peak of the signal, as depicted in Figure 7. At very high frequencies, however, the output signal seemed to undergo shape distortion, change in phase, and a reduction in its magnitude. For example, the waveforms of the input and the output signals of the amplifier obtained at a frequency of 500 kHz are depicted in Figure 8 for various temperatures. It can be clearly seen that these changes are not limited only to the test temperature of –185 °C, but rather throughout the test temperature range. The decrease in the amplitude of the output signal, however, is most significant at –185 °C. This behavior in the amplifier's performance at high frequencies was the same for both the pre- as well as the post-cycling conditions. Once again, any temperature-induced changes in the device properties were transitory in nature as the amplifier fully recovered to its original characteristics when re-tested at room temperature.

Conclusion

Two devices of the Analog Devices OP284FP precision operational amplifier have been evaluated for potential use in low temperature environments. These devices, which were 8-pin plastic DIP packages, were industrial grade rated for operation in the temperature range of –40 °C to +125 °C. The devices were characterized for physical integrity and packaging reliability under exposure to extreme temperatures. Electrical evaluation in terms of signal gain and phase shift was also carried out in the temperature range of +125 °C to -185 °C. Limited thermal cycling was also performed on the two devices. The results from this work indicate that these devices experienced no physical degradation with regard to the internal material used by these devices or their exterior packaging due to either low temperature exposure or thermal cycling. Their electrical performance, however, is limited to –150 °C as the gain and phase properties degrade greatly at test temperature of –185 °C. Nonetheless, the low temperature limit of –150 °C by far exceeds their manufacturer's operating temperature specification. Further testing and long term comprehensive characterization are needed to fully establish their potential use and reliability for extreme temperature applications.

References

1. Analog Devices Inc., OP284 Data Sheet, Rev. 0, 1996.

Acknowledgments

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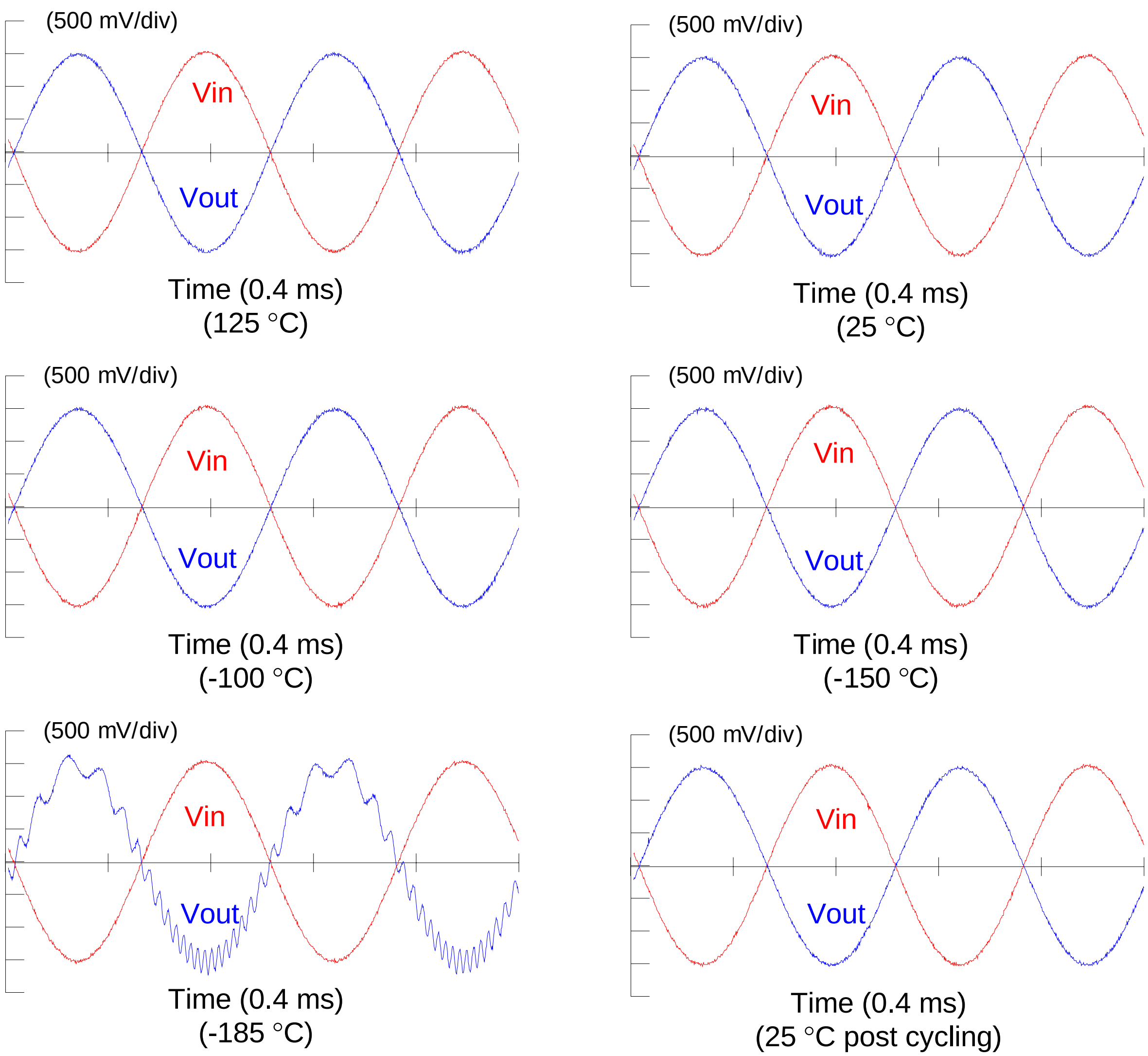

Figure 6. Input and output waveforms at various temperatures at 1 kHz.

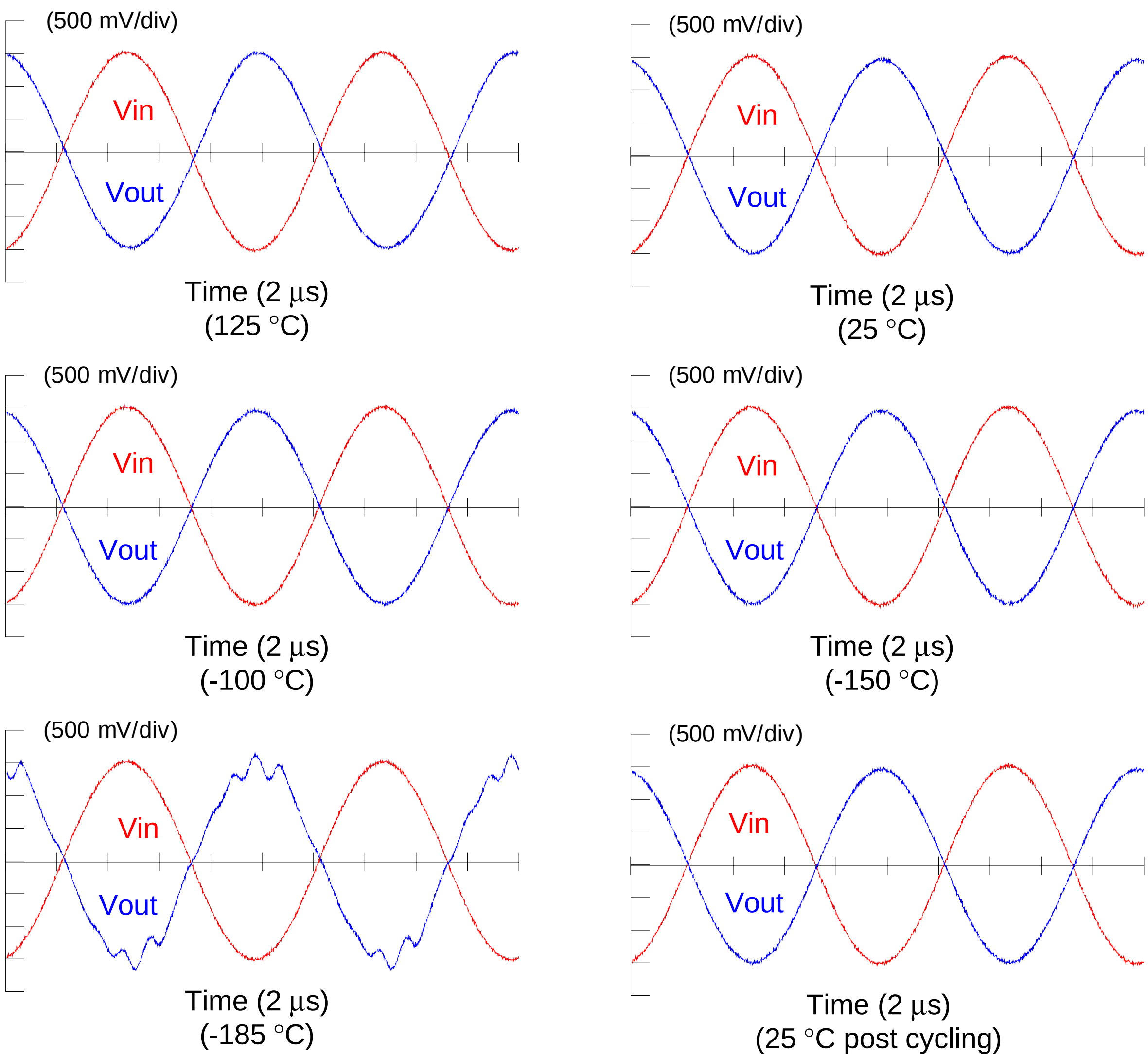

Figure 7. Input and output waveforms at various temperatures at 10 kHz.

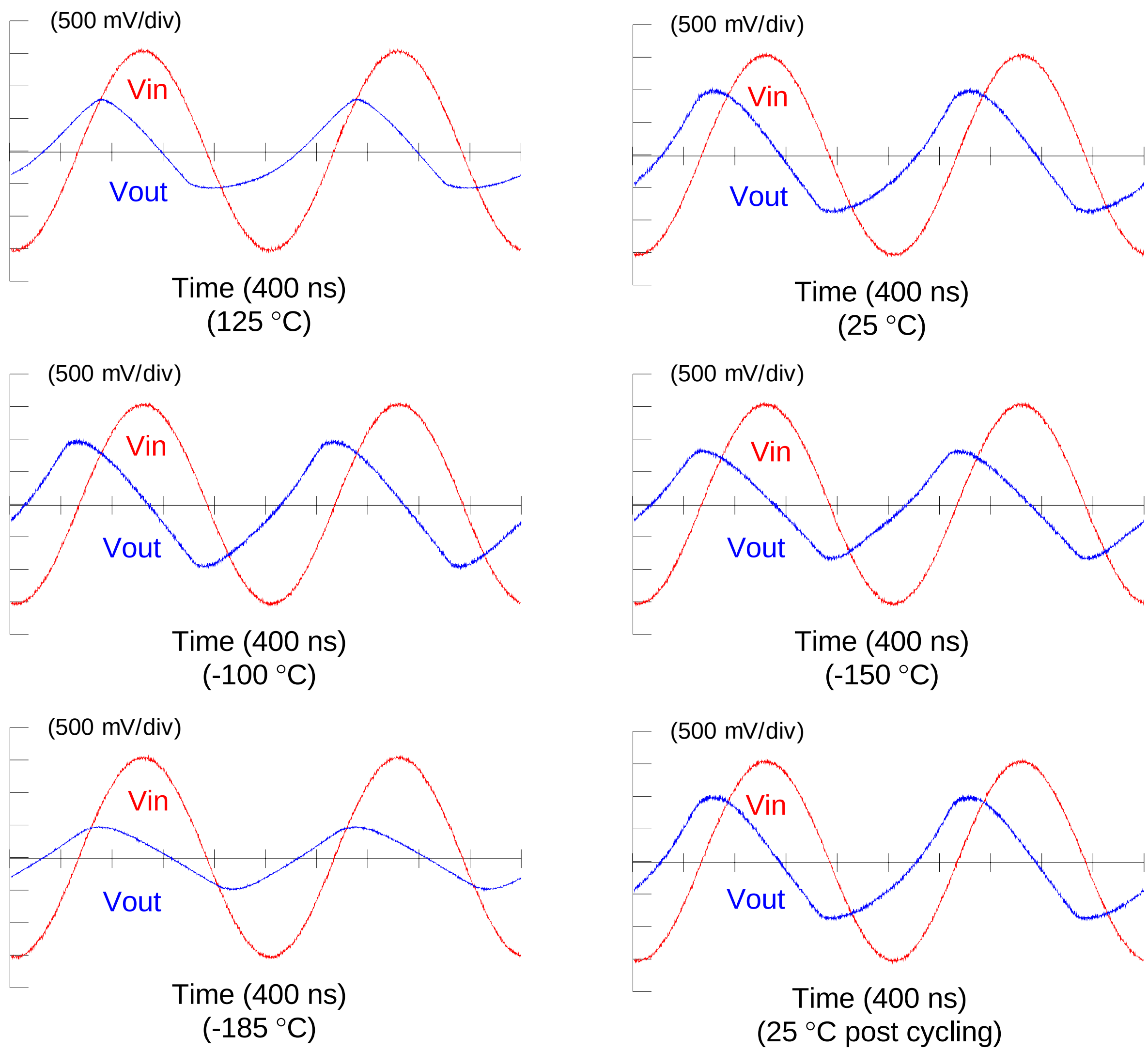

Figure 8. Input and output waveforms at various temperatures at 500 kHz.